SOURCES OF RESISTANCE TO *HETERODERA AVENAE* WOLL. IN NEW SOUTH WALES

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Synopsis

Australian cultivars of wheat, oats, barley and rye and European cereal cultivars and lines resistant to various European pathotypes were tested over four years for resistance to the pathotype of the cereal cyst nematode, *Heterodera avenae*, present in New South Wales. Amongst the Australian cultivars three of 42 wheats, eleven of 15 oats, none of 11 barleys and two of 3 ryes showed resistance. The European barleys Marocaine 079 and Morocco and the Cc 4658 line of *Avena sterilis* were resistant. New South Wales nematode populations resemble Victorian populations in their reactions on the European cereals. Australian populations resemble mixtures of certain European pathotypes in their reactions on European barleys, but differ in their reaction on Loros wheat.

Introduction

Heterodera avenae Woll., the cereal cyst nematode, attacks winter cereals throughout Europe, in Australia (New South Wales, South Australia, Victoria, Western Australia), Canada (Ontario), Israel, Morocco, South Africa, Japan and India (Kort, 1972). By growing isogenic lines of barley differing only in the presence of a single gene for resistance to *H. avenae*, Cotten (1967*a*), in Britain,

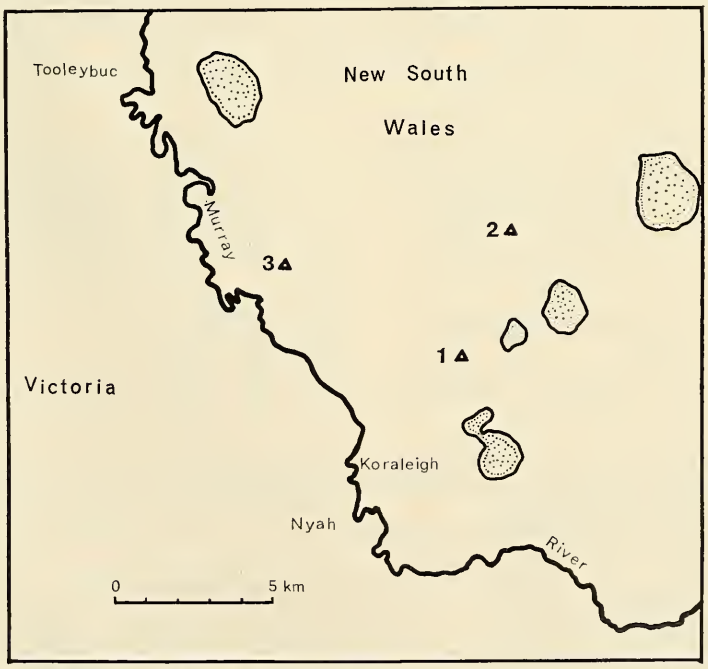

Fig. 1. Sites where soil was collected and field trials were carried out. These sites enclose the area known to be infested with *H. avenae* in New South Wales.

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showed that this nematode can reduce yield by 20% on heavily infested land. Dixon (1970) showed that for every ten eggs of *H. avenae* per g of soil before sowing, yield of oats fell 376 kg/ha, yield of wheat 188 kg/ha and yield of barley 75 kg/ha. The only practical control on infested land is to grow other crops or cereal cultivars which do not allow the nematode to multiply (resistant cultivars). Resistant cultivars not only outyield susceptible ones in heavily infested soil (Cotten 1967*a*, 1970 ; Mukhopadhyaya *et al.*, 1972) but also the yield of following susceptible cultivars (Cotten, 1967*a* ; Williams, 1970) is increased because nematode numbers are reduced. In Europe at least six pathotypes have been distinguished on the basis of host resistance (Cook and Williams, 1972). In Victoria, Brown (1969) has found a single pathotype which differs from those described elsewhere. Thus it is necessary to determine what pathotypes occur in a newly discovered infested area before cultivars incorporating resistance and adapted to the area can be bred.

In New South Wales, *H. avenae* is found over a very small area (McLeod, 1973 ; Fig. 1). However, ready access to sources of resistance effective against local populations would be advantageous should the nematode spread. The present work was done in New South Wales with the aims of (i) identifying the pathotype present by testing cereal cultivars and lines known to be resistant to European pathotypes and (ii) locating sources of resistance amongst Australian cultivars used or of potential use in New South Wales.

Table 1

Origin of seed and reactions of European cultivars and lines to pathotypes of Heterodera avenae

Cultivar or line	Origin of seed	Recorded reactions to pathotypes
Wheat		
Loros Aus 2897	Burnley, Victoria	**R** D1, D2*
		S V
Avena sterilis		
Cc4658	Wageningen, The Netherlands	Resistant to all pathotypes tested†
Barley		
7187CoSS	Rothamsted, England	Susceptible to all pathotypes tested
Drost	Rothamsted, England	**R** D1, NA, NB, ND, B1‡
		S D2, NC, B2,‡ V
191	Rothamsted, England	**R** D1, D2, NA, NC, ND‡
		Rp V
		S NB, B3‡
No. 14	Rothamsted, England	**R** NA, NB, B1‡
		Rp B2,‡ V
		S NC, ND‡
Marocaine 079 Morocco	Wageningen, The Netherlands	**R** NA, NB, NC, ND, B1, B2,‡ V
		S B3‡

Aus = prefix for accessions in the Australian Wheat Collection.
R = resistant; **Rp** = partially resistant; **S** = Susceptible.
D1, D2 = Danish pathotypes.
NA, NB, NC, ND = Netherlands pathotypes.
B1, B2, B3 = British pathotypes.
V = pathotype in Victoria (Brown, 1969 ; Brown and Meagher, 1970).
* Nielsen (1966).
† Cook and Williams (1972).
‡ Hayes and Cotten (1971).

Materials and Methods

European cultivars and lines used in pathotype testing and their known reactions are shown in Table 1. Ten single plants of each variety were grown in pots of 800 g of soil in a glasshouse. Soil from three sites, enclosing the known

infested area in New South Wales (Fig. 1) was tested. Tests were started in May each year in 1970, 1971 and 1972. After 12 weeks, new white cysts on roots and in the soil in each pot were counted, using the method of Cotten (1963), except that cysts collected on the 300 μm-aperture sieve were counted directly by placing it in a tray of water.

Australian cultivars were tested in the field at site 1 (Fig. 1). The soil in this district is a sandy solonised brown soil (Mallee soil) (Stace *et al.*, 1968). Seed was sown in May 1971, 1972, 1973 and 1974 in drill rows 100 m long and 36 cm apart. District rainfall was 416 mm (18% above average) in 1971, 260 mm (27% below average) in 1972, 684 mm (94% above average) in 1973 and 730 mm (104% above average) in 1974 (Australian Bureau of Meteorology, 1971–74). In September each year, 20 plants were dug randomly from each row, freed of excess soil, washed carefully and the number of cysts on the roots counted. Cultivars which were obviously susceptible, with an average of more than four cysts per plant, were not sown in following years, except that Festiguay wheat, which had an average of eight cysts per plant in 1971, was sown in succeeding years and Dural and Duramba wheats, which had averages of five and nine cysts per plant respectively in 1973, were sownagain in 1974.

Results and Discussion

Results of tests with European lines and cultivars are shown in Table 2 and with Australian cultivars in Table 3.

Table 2

Production of cysts on European cereal cultivars and lines by Heterodera avenae *from Koraleigh, New South Wales*

Number of cysts on ten plants as a percentage of number on ten susceptible control plants

Cultivar	Site 1			Site 2		Site 3	Reaction
	1970	1971	1972	1971	1972	1970	
Wheat							
Loros Aus 2897*	—	447	307	200	537	—	S
*Avena sterilis** (Cc4658)	1	1	0	0	0	0	R
Barley							
7187CoSS†	135	584	740	127	1250	130	
Drost	100	100	100	100	62	100	S
191	16	15	12	6	10	12	Rp
No. 14	12	16	15	12	5	19	Rp
Marocaine 079	3	9	5	0	2	0	R
Morocco	0	5	5	5	0	1	R

R=resistant; Rp=partly resistant; S=susceptible.

* Number of cysts on ten plants shown.

† Control susceptible cultivar, number of cysts on ten plants shown.

Uniformity of eastern Australian populations

Tests of the European cultivars and lines in soil from different sites and in different years gave similar results (Table 2) and provide no evidence for more than one pathotype. The reactions are in agreement with those reported in Victoria (Brown, 1969). Twenty-five Australian cultivars tested both in Victoria and New South Wales have reacted similarly (Table 3). It is concluded that New South Wales and Victorian populations of *H. avenae* belong to the one pathotype, as is to be expected from the geographical position of the infested areas.

TABLE 3

Numbers of cysts of Heterodera avenae *on Australian cultivars of wheat, oats, barley and rye grown in naturally infested soil at Koraleigh, New South Wales*

Cultivar	Number of cysts per plant (mean of 20 and standard error)			
	1971	1972	1973	1974
Wheats				
Bencubbin	—	—	>20*	—†
Bokal	—	—	>20	—
Condor	—	25±5	—	—
Darkan	—	—	>20	—
Dural	—	—	5±1	7±3
Duramba	—	—	9±2	9±5
Eagle	18±3	—	—	—
Egret	—	16±1	—	—
Emblem	—	—	>20	—†
Falcon	11±3	—	—	—
Festiguay	8±·5	1±·4	2±·5	5±1
Gabo	—	—	15±1	—†
Gamut	16±2	—	—	—
Gatcher	14±3	—	—	—
Glenwari	—	—	>20	—†
Glaive	11±2	—	—	—
Halberd	—	—	>20	—
Heron	26±6	—	—	—†
Insignia	—	—	>20	—†
Isis	—	—	>20	—†
Kite	—	14±1·4	—	—
Mendos	—	—	>20	—
Mengavi	—	—	14±1	—
Mersey	—	—	>20	—
Olympic	18±3	—	—	—†
Pinnacle	32±3	—	—	—†
Robin	21±5	—	—	—
Spica	13±3	—	—	—
Summit	24±2	—	—	—†
Sun 17 I	—	—	—	13±4
Sun 17 L	—	—	—	>20
Tarsa	—	38±5	—	—
Teal	>20	—	—	—
Timgalen	16±2	—	—	—
Winglen	20±8	—	—	—
Winter DARF	—	—	>20	—
Winter Heron	—	—	—	>20
Wren	19±3	—	—	—
Zenith	—	—	—	>20
WW 33	—	—	>20	—
WW 97–2	—	—	—	>20
IIB	—	—	—	>20
Oats				
Acacia	·9±·3	0	·5±·2	0†
Algerian	1±·4	2±·1	1·5±·6	0†
Avon	·1±·06	·2±·1	0	0†
Bundy	2±·5	2±·3	3±1	0†
Cassia	—	>20	—	—
Cooba	·7±·4	·5±·2	·2±·1	0
Coolabah	>20	—	—	†
Fulghum	7±1	—	—	—†
Irwin	—	—	—	0
Klein 69B	·6±·3	·1±·07	0	0
Mugga	5±·6	—	—	—†
Swan	—	—	—	2±·4
P4315	2±·8	·4±·2	1±·3	0

* All plants with more than 20 cysts.
† Tested in Victoria by Brown and Meagher (1970) with similar results.

TABLE 3—*continued*

Numbers of cysts of Heterodera avenae *on Australian cultivars of wheat, oats, barley and rye grown in naturally infested soil at Koraleigh, New South Wales*

Cultivar	Number of cysts per plant (mean of 20 and standard error)			
	1971	1972	1973	1974
P4319	—	2±1	0	·5±·6
M1354	—	—	·6±·2	2±·3
Barley				
Abyssinian	15±3	—	—	—
Beecher	37±4	—	—	—†
Bussell	11±2	—	—	—
Clipper	14±3	—	—	—†
Dampier	11±2	—	—	—†
Ketch	—	13±2	—	—
Lara	—	13±1·5	—	—
Noyep	6±1	—	—	—†
Prior	11±3	—	—	—†
Resibee	14±1	—	—	—†
Weeah	10±2	—	—	—†
Rye				
South Australian	0	0	0	—†
Strain 8	6±1	—	—	—†
Weethalle	·4±·1	0	0	—

* All plants with more than 20 cysts.

† Tested in Victoria by Brown and Meagher (1970) with similar results.

Relation of Australian and overseas pathotypes

Most of the wheat cultivars tested proved susceptible whereas the majority of oat varieties were resistant (Table 3). A similar situation occurs in Victoria (Brown and Meagher, 1970). However, in Europe, most commercial oat cultivars are susceptible (Cook and Williams, 1972). Whether this is due to genetic differences between European and Australian oat cultivars or to nematode differences is not clear. Franklin (1951) and Cotten (1967*b*) found oat cultivars which were resistant or partly resistant when tested in Australia (Millikan, 1938 ; Brown and Meagher, 1970) but susceptible when tested in England. This suggests differences between nematode populations rather than host differences.

The partial resistance of 191 barley and the susceptibility of Loros wheat (Table 2) rule out the presence of Danish pathotypes 1 and 2 (Table 1). The susceptible reaction of Drost and partial resistance of 191 could be explained by the presence of a mixture of two European pathotypes. For example Netherlands C, able to form cysts on Drost, mixed with a smaller number of Netherlands B, able to form cysts on 191 (Table 1), could give this reaction. Further, Netherlands C forms more cysts on Drost than on No. 14 (Kort, personal communication) as do New South Wales populations (Table 2). However, no line of Loros wheat has been found susceptible to C (Kort, personal communication) whereas both Victorian and New South Wales populations form cysts freely on the line of Loros wheat used in these tests (Brown, 1969 ; Table 2). British pathotype 2 mixed with a smaller number of 3 could give a susceptible reaction on Drost and a partially resistant reaction on 191 and No. 14 (Table 1). British pathotype 3, however, would form as many cysts on Marocaine 079 and Morocco as on 191 (Cook and Williams, 1972) but this is not so for the New South Wales nematode. Thus, although there are resemblances, there are important differences which indicate that Australia has a pathotype differing from any known in Europe.

The results perhaps indicate a relationship with the pathotype in Rajasthan, India, where Gill and Swarup (1971) report that Drost is susceptible and 191 is only partly resistant. However, the Indian pathotype reproduces on *Zea mays* L. (Gill and Swarup, 1971 ; Yadav and Verma, 1971) but our population failed to form cysts on this host in glasshouse tests in which Drost barley plants had an average of 88 cysts per plant.

Sources of resistance for use in New South Wales

Only three of the Australian wheat varieties tested–Festiguay, Dural and Duramba–showed a degree of resistance (Table 3). Festiguay is a cross between Festival and an introduction from Uruguay, Uruguay C10837 (Macindoe and Walkden Brown, 1968). Resistance has evidently come from the Uruguay introduction since Festival is susceptible in Victoria (Brown and Meagher, 1970). This cultivar is suited to conditions in the north-western wheat belt of New South Wales, but it is being replaced by the susceptible Tarsa (Matheson, 1972). Its resistance could be introduced into other cultivars more suited to the southern wheat belt. Dural and Duramba are drum wheats (cultivars of *Triticum durum* Desf.) and their resistance would be more difficult to use. Millikan (1938) found that *T. durum* cultivars were, on the whole, more resistant than *T. aestivum* L. cultivars at Nhill in Victoria.

The resistance of Cooba oat is fortunate because it is the most widely grown oat in New South Wales (Walkden Brown and Fitzsimmons, 1972). Coolabah is a new cultivar suitable for the marginal rainfall areas where the nematode now occurs but it has the disadvantage of being susceptible. The susceptibility of Cassia is also disadvantageous since this is now recommended as a gradual replacement for resistant Avon (Komoll and Fitzsimmons, 1973), the third most widely grown oat in New South Wales. A further possible source of resistance in oats is that available in the Cc4658 of *Avena sterilis* L. (Table 2).

All of the Australian barley cultivars tested (Table 3) allowed too many cysts to develop to be considered resistant. However, two of the European test cultivars, Marocaine 079 and Morocco, were resistant (Table 2) and could be used as sources for introducing resistance into locally adapted cultivars. Barley 191, the source used in breeding resistant barleys in Britain (Hayes and Cotten, 1971), would be less effective than these since in all but one test it supported considerably more cysts (Table 2).

South Australian rye and Weethalle rye, a selection of the former, are highly resistant as has been found in Victoria (Brown and Meagher, 1970). These could be used directly to prevent population build-up.

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